Information Modeling for Direct Control of Distributed Energy Resources

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***Abstract*— We present an architecture for an unbundled liberalized electricity market system where a virtual power plant (VPP) is able to control a number of distributed energy resources (DERs) directly through a two-way communication link. The aggregator who operates the VPP utilizes the accumulated flexibility of the DERs to participate in the electricity market on equal terms with conventional power plants. The focus of this paper is the interface between the DERs and the VPP: this interface must enable the aggregator to overview the total DER flexibility and remote control the DERs to provide a desired accumulated response. In this paper, we design such an information model based on the markets that the aggregator participates in and based on the flexibility characteristics of the remote controlled DERs. The information model is constructed in a modular manner making the interface suitable for a whole range of different DERs. The devised information model can serve as input to the international standardization efforts on DERs.**

I. Introduction

With an increasing focus on climate-related issues and rising fossil fuel prices, the penetration of renewable energy sources is likely to increase in the foreseeable future throughout the developed world [1]. Many actions are taken from a political point to increase the penetration of renewables: in the US almost all states have renewable portfolio standards or goals ensuring a certain percentage of renewables [2]. Similarly, the commission of the European Countries has set targets increasing the share of renewables in the final energy consumption to 20 % by 2020 [3] while China has doubled the wind power production every year since 2004 [4]. In Denmark, the 2020 goals 35 % sustainable energy and 50 % wind power in the electrical power consumption [5].

As a consequence of this increase in renewables, the power system is moving from a setup with few centralized conventional power plants to a setup with a large number of distributed, smaller production units [6]. As an example of this evolution, Denmark has moved from a situation with a total of 16 central power plants in 1980, to a system which today consists of 16 central power plants, 1000 local combined heat and power plants and around 6000 wind turbines [7].

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The conventional power plants are currently the main providers of grid stabilizing services. As they are phased out gradually and replaced by distributed energy resources (DERs), alternative sources of ancillary services must be found. One of the approaches towards alternative ancillary services is the *smart grid* concept, where DERs such as smaller generation devices or flexible power consumers take part in the balancing effort [8], [9]. The basic idea is to let an *aggregator* manage the accumulated flexibility of the DERs to provide responses similar to those of the conventional power plants. This allows the aggregator to participate in the unbundled electricity markets using DER flexibility.

Control of DERs to support grid stability has been discussed as early as the 1980s [10]. Since, this topic has received much attention research perspective [11], [12], [13]. A few research examples in the area of smart grid DER control are: optimization of domestic heat pumps [14], [15], supermarket cooling systems [16], [17], domestic refrigerators [18], [19], and electrical vehicles [20], [21]. While these works, and many more, discuss methods for remote control of DERs, they do not discuss who the DERs should communicate their flexibility to the VPP.

It is, however, a crucial element in the aggregation and control of flexibility is that the DERs are able to represent their flexibility in a generic manner, such that the aggregator can obtain an overview of the available flexibility and control the DERs accordingly. This *flexibility interface* between DERs and VPP is the focus of this work. In the literature, standards exist defining protocols for control of substations such as wind turbines, combined heat and power plants etc. See, [22], [23]. Also, standards exist for remote control of various domestic appliances [24], [25]. However, these standards are not developed with the focus on flexibility aggregation for market participation and are thus not directly applicable in this setup.

In this paper, we show how a flexibility interface information model can be developed by identifying the flexibility characteristics of the DERs it is desired to be able to control, and by considering the markets that the aggregator should be able to participate in. We show this by identifying the flexibility characteristics of a number of key DERs and by examining the electricity markets. Based on this, we design and present an information model for the flexibility interface.

The structure of the paper is as follows. First, in Section II, we describe the overall setup and architecture; following, in section III, we describe a number of DERs and identify their flexibility characteristics. In Section IV, we describe the services that the aggregator should be able to provide, and in Section V, we describe the role of the VPP. Finally, in Section VI, we present an overview of the developed flexibility interface information model and in Section VII, we conclude the work.

II. Overall Setup

This section briefly outlines the topic of this paper: the interplay between a number of DERs and an aggregator through a flexibility interface. Later, in sections III, IV and V, more detailed descriptions of DERs, services and the aggregator are presented.

A. Distributed Energy Resources

DERs are smaller production units such as wind turbines or photovoltaics, or flexible consumption units such as heating and cooling systems or electric vehicles. Generally, the flexibility of each DER is smaller than the threshold for bidding into the electricity markets; it requires aggregation with other DERs to reach a volume large enough to enter the markets.

A DER is moreover characterized by being equipped with a local controller enabling the unit to operate autonomously. This local controller is assumed able to estimate the available flexibility of the DER, i.e. how flexible the DER is in the production/consumption of active/reactive power. Additionally, the DER is able to be remote controlled by receiving commands from an external controller; this allows for an aggregator to actuate the DER flexibility.

The purpose of the remote control is to utilize the flexibility of the DER without interfering in the primary process of the DER. We illustrate this ability to perform local control while allowing remote control with two examples. As an example from the demand side, we consider a supermarket freezer system. A freezer system is able to ensure correct cooling of goods, and within limits it is also able to offer flexibility in the active power consumption due to the large thermal time constants of the system. This flexibility can be remotely controlled by an aggregator.

This paper deals with aggregation and management of DERs via remote control of flexibility, enabling a portfolio of DERs to provide an accumulated response large enough for actual bids in the power and reserve markets.

B. Direct Control

Generally, two main approaches are envisioned when describing aggregation of DERs and in particular flexible consumption devices. These approaches are referred to as *direct control* and *indirect control* of the device [26], [27]. Direct control refers to a setup where two-way communication exists between VPP and DER: the DER reports its local flexibility to the VPP and the aggregator controls the DER through the VPP based on this information. The basis for direct control is an agreement/contract between each DER owner and the aggregator that uses the VPP. The contract describes to what extend and at which cost the aggregator is allowed to utilize the DER flexibility. In contrast, *indirect control* refers to a setup where a one-way signal is sent from aggregator to DER without any direct feedback from the DER (possibly the aggregator will get indirect feedback through grid measurements etc.).

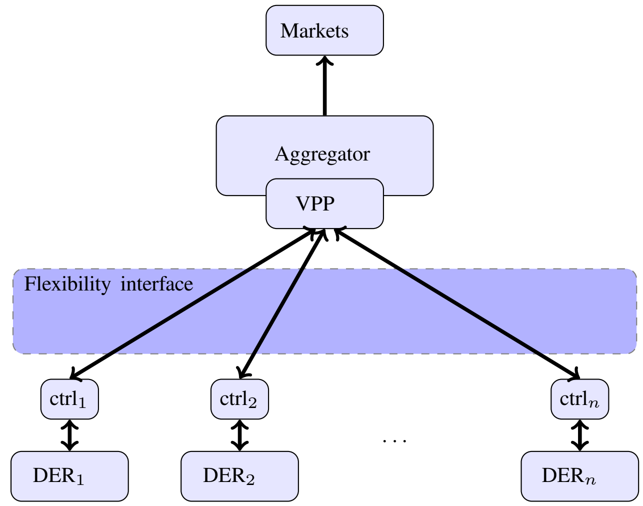

Fig. 1. Aggregator manages n DERs through the VPP via a flexibility interface.

This paper deals exclusively with a *direct control* setup between the DERs and the VPP. The flexibility interface information model developed in this work therefore only refers to the case where the DERs are directly controlled by an aggregator through a VPP.

C. Aggregator and VPP

The flexibility of a single DER is too small to make isolated bids into the electricity markets; for example, the threshold for primary frequency control reserves is 300 kW in Eastern Denmark [28]. For this reason, several DERs must be aggregated in order to achieve sufficient quantities of active or reactive power for bidding. Therefore, the role of the aggregator is to make contracts with the DERs, allowing the aggregator to utilize the DER flexibility through the VPP. Consequently, this enables the VPP to

- retrieve information of the flexibility limits of the DERs
- retrieve information of the cost of utilizing the flexibility
- manage the DERs within the given flexibility limits.

D. Flexibility Interface

We are now able to illustrate and describe the overall setup of this paper, see Fig. 1. The figure illustrates an aggregator managing a total of n DERs through its VPP. This enables the aggregator to bid aggregated flexibility into the power markets. The flexibility interface, which is the topic of this work, is located between the local controllers of the DERs and the aggregator's VPP managing the DERs. The interface facilitates the two-way communication link making it possible for the DERs to report their flexibility to the VPP of the aggregator and making it possible for the aggregator to manage the DERs.

III. Distributed Energy Resources

The purpose of this section is to identify the various DER flexibility characteristics that the flexibility interface must be able to handle. These characteristics form a background for the actual flexibility interface presented later.

In [29], flexibility descriptions of a number of DERs are presented. In terms of power flexibility, the key DERs include:

- space heating systems
- electrical vehicles
- diesel generators
- hydro power plants
- domestic appliances
- combined heat and electricity generation
- photovoltaic systems.

By examining the functionality of these DERs, their flexibility characteristics can be identified [29] resulting in a list of various types of characteristics. These characteristics are presented in Table I. The flexibility interface must be able to handle these different flexibility characteristics.

IV. Supported Services

In this section we describe the services that the aggregator must be able to deliver and how this affects the requirements to the flexibility interface. The services are divided into three main areas: distribution level services, transmission level services and day-ahead/intra-day services.

A. Distribution Level Services

The distribution level deals with the power lines from 0.4 kV up to 60 kV. Currently, distribution level markets do not exist but can be envisioned in the future electricity system as e.g., described in the Danish iPower project [30].

1) Distribution Grid Congestion Management: It is anticipated that congestion management on the distribution grid will become an issue in the future when larger quantities of for instance heat pumps and electric vehicles are introduced, significantly increasing the load. Therefore, distribution grid congestion management markets might be introduced in the future.

2) Local Voltage Control: It is anticipated that local voltage control will become an issue of increasing importance, as more DERs are put into operation. In cases where many DERs will be located on the same distribution line, this may affect the voltage quality, for example with many photovoltaics on the same line. It is possible to resolve voltage problems via grid codes by embedding voltage controllers at the DERs, but this method would mean that the producers of the DERs (and eventually the consumer) will be the ones paying for the grid voltage control. Another approach is to establish a market for local voltage control where voltage stabilizing services can be bought or sold.

B. Transmission Level Services

At the transmission grid level, the transmission system operators (TSOs) are responsible for secure and reliable system operation. This entails keeping balance between production and consumption as well as maintaining power quality and ensuring a stable transmission system. Generally, in an unbundled power market, TSOs do not own production units, they therefore have to procure ancillary services from suppliers.

1) Primary Frequency Reserve: The primary frequency reserve is an automatic control used in frequency control. A main target for the primary control is to stabilize the frequency in case of major outages of either loads or suppliers. The primary control reserve is required to sustain until relieved by the secondary control [31]. The time scale for activating primary frequency reserve is in the area of 10-30 seconds. The primary frequency reserve must be based on a local control loop using local system frequency measurements.

2) Secondary Frequency Reserve: The secondary frequency reserve, often referred to as the AGC (Automatic Generation Control) is activated by a TSO reference signal. The objective of the secondary control is to restore power balance in a control area, to take part in stabilizing the frequency, and to restore the primary reserve [32], [33]. The time scale for activation of secondary reserve is in the magnitude of 15 minutes.

3) Tertiary Frequency Reserve: Tertiary control is a reserve that can be activated manually by the TSO. Upon activation, the provider of the reserve will change the planned operation such that the necessary upward or downward regulation is achieved. The purpose of tertiary reserve is to resolve persistent balance or congestion problems and in this way restore the secondary and primary frequency reserve [31]. The time scale of activating tertiary reserve is in the time-frame from seconds up to 15 minutes [32].

4) Mvar-bands (Mega volt-ampere reactive bands): The Mvar-bands are used in the Nordic system to represent certain limits on the flow of reactive power between the distribution and transmission grid. As an example, Denmark is divided into 15 Mvar regions. In each region, Mvar limits are given describing the maximum/minimum reactive power flow to/from the regions. The goal is to restrict the transport of reactive power in the transmission grid such that there is a high active power capacity. Because of these bands, the distribution system operators (DSOs) are required to control the exchange of reactive power in case the bands are in risk of being violated. The DSOs will typically perform this control by activation/deactivation of shunt capacitors, static var compensators, STATCOM generators or synchronous condensers. It would, however, also be possible for certain DERs to provide such reactive power services, e.g., wind turbines, combined heat and power plants. Therefore it might be possible to envision a future market for trading reactive power [34].

C. Day-ahead and Intra-day Services

In the day-ahead and intra-day markets, active power is sold and bought for one hour slots. The supply and demand will determine the market price for the active power.

Flexibility characteristic	Examples
Continuous/discrete active/reactive power limits	Electric vehicle able to consume power in the interval 1 kW to 6 kW.
Energy limitations	Refrigeration system able to store a total of 1 kWh.
Power reference tracking possible	Heat pump for space heating that can follow a remote power reference.
Power scheduling possible	Large scale chiller system able to perform 24 hour power scheduling.
Maximum/minimum runtime/stoptime	Heat pump must run for at least 15 minutes when started.
Minimum down-time	Heat pump must stay turned off for at least 15 minutes after turned off.
Fixed consumption, flexible activation time	Domestic appliances with flexible startup time (within certain time span).
Energy storage dynamics	Freezer system where the energy loss depends on temperature difference to ambience.
Coupled active/reactive power production/consumption	PQ-capabilities in inverter systems.
Energy storage with terminal energy constraint	Charging of an electric vehicle battery that must be fully charged at certain time.
Active/reactive power ramping limitations	Power ramping limits of wind turbine.
Flexibility costs	**Examples**
Energy level dependent cost	Discomfort cost for temperature deviations in heated houses.
Active/reactive power production dependent cost	Cost for derating the active production of a wind turbine.
Unit startup/shutdown costs	Cost for starting up a generator.
Activation time dependent cost	Cost related to the startup time of a flexible startup time appliance.

TABLE I
FLEXIBILITY CHARACTERISTICS AND COSTS.

1) Day-ahead Market: In the day-ahead market, power is bought and sold for the 24 hours of the following day. The Nordic day-ahead market Elspot, closes at 12:00 CET every day; by this time, bids for buying and selling power for the 24 hours of the following day must be submitted. At 13:00 CET, the resulting spot-prices and traded volumes are published.

2) Intra-day Market: In the intra-day markets, power is bought and sold for one-hour time slots closer to the operational hour. In the Nordic market, the intra-day market Elbas closes 45 minutes before the hour of operation.

D. Service Characteristics

Based on these descriptions, we sum up the characteristics relevant for the design of the flexibility interface information model.

- *Time scales:* from minutes in the faster ancillary services, up to 36 hours in the day-ahead spot market.
- *Geographical location*: the location of the DER in the grid is important in the case of distribution grid services.
- *Local control or remote control*: in the case of primary frequency reserve, the grid frequency must be measured locally and a local control loop determines the activation of the primary reserve. In contrast, secondary reserve provision must be activated based on remote signals.
- *Combined deliveries*: some services can only be provided by either only consumption units or only production units. Therefore it is necessary to distinguish between production and consumption units.
- *Active/reactive power*: both active and reactive power must be communicated through the flexibility interface.

V. VIRTUAL POWER PLANT

The VPP must be able to overview the total flexibility of the DERs presented in Section III and manage this flexibility to participate in the markets described in Section IV. Several VPP control strategies can be imagined for managing the DERs to provide the contracted services. In, e.g. [35], [36], [37], a VPP control objective on the following form is used:

$$\begin{array}{ll} \text{minimize} & \displaystyle\sum_{i\in\mathcal{I}}\sum_{\tau\in\mathcal{T}} \ell_i(x_i(\tau),u_i(\tau)) \\ \text{subject to} & x_i(\tau)\in\mathcal{X}_i(\tau),\ u_i(\tau)\in\mathcal{U}_i(\tau), \quad \tau\in\mathcal{T}, i\in\mathcal{I} \end{array}$$

where $\mathcal{I}$ is the set of all DERs and $\mathcal{T}$ is the control time horizon; the optimization variables x_i, u_i represent states and inputs of DER i, respectively; the sets $\mathcal{X}_i(\tau), \mathcal{U}_i(\tau)$ represent the dynamics and constraints of DER i while $\ell_i(x_i(\tau), u_i(\tau))$ is the control objective of DER i representing the costs of remote controlling the given DER.

This VPP control strategy is presented to illustrate an important requirement to the flexibility interface: the DERs should be able to communicate not only dynamics and constraints $\mathcal{X}_i, \mathcal{U}_i$ but also objective functions $\ell_i(x_i(\tau), u_i(\tau))$. This will allow the VPP to activate the DERs' flexibility in a cost effective manner, e.g., by activating the cheapest set of DERs that collectively are able to provide the contracted service.

Further, the VPP strategy presented above illustrates exactly how to apply the flexibility interface to manage DERs: the individual DERs will in a standardized way through the flexibility interface communicate the current state x_i, the objective function ℓ_i, the given constraints $\mathcal{X}_i, \mathcal{U}_i$, etc. With a well defined flexibility interface, different devices will be able to communicate objectives and constraints in a way that the VPP can interpret; hereby, the VPP is able to optimize over the entire portfolio. In a similar manner, the flexibility interface provides a standardized way for the VPP to control the individual DERs. By communicating the control signal, represented as u_i above, through the flexibility interface, the DERs will be able to interpret this control signal and alter the local operation accordingly.

VI. Flexibility Interface

In this section we present a flexibility interface information model. This information model is constructed directly based on the identified flexibility characteristics (Section III) and the markets the aggregator should be able to participate in (Section IV).

A. Flexibility Interface Information Model

The flexibility interface is constructed as follows. The identified DER flexibility characteristics (Table I) relevant for the provision of services in the power markets are divided into a number of *flexibility blocks*. These flexibility blocks are presented in Table II. Each flexibility block represents a certain flexibility aspect: a block denoted *active power* is able to describe active power flexibility of a DER; another block denoted *flexible startup time* is able to handle flexibility in the startup time of a DER, etc. The interface handles both production and consumption devices indicated with a generator sign. Based on these flexibility blocks, we can describe the flexibility of a given DER simply by selecting the appropriate blocks. We denote such a collection of flexibility blocks a *flexibility frame*; this concept is illustrated in Fig. 2. In this manner, any DER can be described by selecting the set flexibility blocks relevant for the given device – if the DER is abel to store energy, the *energy storage* block is included; if the DER additionally is characterized by runtime limitations, the *runtime limitations* block should also be included, etc.

Note that while this work describes what information can be communicated over the flexibility interface via the flexibility blocks we do, however, not discuss where the data should be stored on either the VPP side or the DER side. The reason is that the main focus of this work is to model the necessary information required in a direct control setup, but not how the DERs and VPP should collect and store this data.

As illustrated in Table II, the flexibility blocks are labeled as either mandatory [**M**] or optional [**O**], meaning that all DERs *must* use the mandatory blocks in the flexibility model but can *choose* to use the optional blocks. As an example, the *type* block is mandatory such that the aggregator knows the device type and name while the *energy storage* block is optional and should only be used if suitable. In a similar manner, the individual attributes are either mandatory or optional meaning that if a block is included, the mandatory attributes must be specified while the optional attributes should be chosen if relevant. The mandatory blocks are those that describe the device type, the point of connection, and the device status as shown in Table II.

B. Structure

A single DER is associated with a single flexibility frame which consists of a number of flexibility blocks which again consist of a number of attributes. The attributes contain the actual information of the given DER. To give an overview of the attributes, we arrange them in the following categories.

- *Data:* static information provided by the DER, e.g., nameplate information.
- *Status:* DER status information provided by the DER, e.g., whether the device is turned on or off.
- *Local settings:* DER settings provided by the DER, e.g., whether the DER allows remote control or not.
- *Parameters:* local parameters provided by the DER, e.g., limitations in maximum/minimum power consumption/producion.
- *Commands:* commands provided by the aggregator to the DER, e.g., to enable remote control.
- *References:* reference signals provided by the aggregator to the DER, e.g., a reference for power tracking.

Also, each attribute is marked either as mandatory or optional analogous to the flexibility blocks. In Table III, two of the flexibility blocks are presented showing examples of the attributes of a flexibility block.

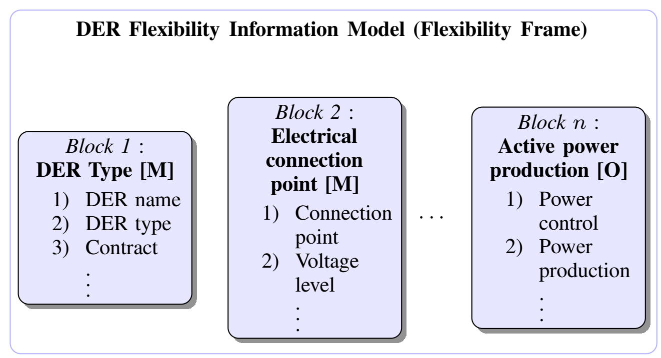

Fig. 2. Illustration of a DER flexibility frame.

C. Modular Information Model

Constructing the flexibility interface in this modular manner allows us to easily extend the interface by constructing additional flexibility blocks. As an example, the presented blocks do not support voltage control, power factor control and delta-mode control. This could be included by specifying blocks relevant for these control types without altering the existing blocks.

It is important to note that the flexibility blocks are constructed such that they are able to express the flexibility of a *single* device. The flexibility interface does not provide a specific method of aggregating the flexibility of multiple devices into one frame. This means that if a set of devices (e.g., all flexible devices in one household) desire using the same flexibility frame, the devices (or a household level aggregator) must aggregate the flexibility such that it conforms with the flexibility blocks. The reason that this work does not support communication between nested VPPs is that this will require certain aggregation techniques, which is outside the scope of this work.

Block name	Explanation	Mandatory or Optional
Type	Nameplate information, consumer or producer	M
Electrical connection point	DER location in distribution grid	M
Status	Ability to be controlled by aggregator	M
Active power	Flexibility in the production/consumption of active power	O
Reactive power	Flexibility in the production/consumption of reactive power	O
Energy storage	Ability to store energy	O
Primary frequency control	Ability to react to local system frequency measurements	O
Flexible startup time	Ability to shift startup time of a fixed production	O
Runtime limitations	Limitations in minimum/maximum runtime and stoptime	O
Log	DER data to be stored at the aggregator for documentation purposes	O
Cost	Cost functions associated with utilization of DER flexibility	O

TABLE II

OVERVIEW OF FLEXIBILITY BLOCKS.

D. Examples

To clearly illustrate the design of the flexibility interface for direct control of DERs, Table III shows the *Power production, active power* block as an example of the flexibility blocks.

VII. Conclusion

In this paper, we describe the need for a flexibility interface in order to allow an aggregator to directly control a portfolio of DERs to collectively provide actual power deliveries. We showed how an information model of such an interface can be constructed by identifying the flexibility characteristics of a number of key DERs and by examining the markets that the aggregator must be able to participate in. A modular approach was taken in the flexibility interface design phase, resulting in an interface where the flexibility of a DER is described by a range of various pre-defined flexibility blocks. Finally, we presented a list of flexibility blocks needed for basic DER operation and presented more detailed descriptions of two of the listed blocks.

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<table>
<tr><th colspan="3">Power production, active power [O]</th></tr>
<tr><th>Attribute name</th><th>Explanation</th><th>M/O</th></tr>
<tr><td colspan="3">Status</td></tr>
<tr><td>Reference tracking status</td><td><table><tr><td>Value</td><td>Explanation</td></tr><tr><td>0</td><td>DER is not remotely controlled for reference tracking</td></tr><tr><td>1</td><td>DER is remotely controlled for reference tracking</td></tr></table></td><td>M</td></tr>
<tr><td>Schedule tracking status</td><td><table><tr><td>Value</td><td>Explanation</td></tr><tr><td>0</td><td>DER is not remotely controlled for schedule tracking</td></tr><tr><td>1</td><td>DER is remotely controlled for schedule tracking</td></tr></table></td><td>M</td></tr>
<tr><td colspan="3">Local settings</td></tr>
<tr><td>Reference tracking allowed</td><td><table><tr><td>Value</td><td>Explanation</td></tr><tr><td>0</td><td>DER does not allow remote control, reference tracking</td></tr><tr><td>1</td><td>DER allows remote control, reference tracking</td></tr></table></td><td>M</td></tr>
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<tr><td colspan="3">Parameters</td></tr>
<tr><td>Continuous power production/consumption intervals</td><td>Power production/consumption limits.
Example: power consumption between 0 and 1.000 W possible.</td><td>O</td></tr>
<tr><td>Continuous power production/consumption limits, time-varying</td><td>Example: power consumption between 0 and 1.000 W possible at day and between 0 and 500 W at night.</td><td>O</td></tr>
<tr><td>Discrete power production/consumption intervals</td><td>Example: power consumption of exactly 0 W or 1.000 W possible (on/off device).</td><td>O</td></tr>
<tr><td>Discrete power production/consumption intervals, time-varying</td><td>Example: power consumption of exactly 0 W or 1.000 W possible at day and only consumption of exactly 0 W possible at night.</td><td>O</td></tr>
<tr><td>Ramping limits</td><td>Upper and lower ramping limits.
Example: up-ramping 100 W/s and down-ramping 200 W/s possible.</td><td>O</td></tr>
<tr><td>PQ-capabilities</td><td>Specification of the relationship between active and reactive power</td><td>O</td></tr>
<tr><td colspan="3">Measurements</td></tr>
<tr><td>Current power production</td><td>Measured power production</td><td>O</td></tr>
<tr><td>Predicted future power production</td><td>Prediction of the future power production</td><td>O</td></tr>
<tr><td>Base power production</td><td>The power production of the DER if not remotely controlled (value can be used for economically settlement).</td><td>O</td></tr>
<tr><td colspan="3">Commands</td></tr>
<tr><td>Reference tracking, activation</td><td><table><tr><td>Value</td><td>Explanation</td></tr><tr><td>0</td><td>Aggregator deactivates remote control, reference tracking</td></tr><tr><td>1</td><td>Aggregator activates remote control, reference tracking</td></tr></table></td><td>M</td></tr>
<tr><td>Remote control, activation</td><td><table><tr><td>Value</td><td>Explanation</td></tr><tr><td>0</td><td>Aggregator deactivates remote control, schedule tracking</td></tr><tr><td>1</td><td>Aggregator activates remote control, schedule tracking</td></tr></table></td><td>M</td></tr>
<tr><td colspan="3">References</td></tr>
<tr><td>Power reference</td><td>Provided by the aggregator when operating in reference tracking.</td><td>O</td></tr>
<tr><td>Power schedule</td><td>Provided by the aggregator when operating in schedule tracking.</td><td>O</td></tr>
</table>

TABLE III

EXAMPLE OF TWO FLEXIBILITY BLOCKS.

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